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Maurice Farman, Observatoire de Chevreuse à Jagny, par Dampierre (Seine-et-Oise), France (proposed by Camille Flammarion);
Willie Venner Merrifield, B.A., Head Master, Nautical College, Byrom Street, Liverpool (proposed by W. H. Besant);
Isaac Molloy, M.A., Lützen, Glenageary, Kingstown, Dublin (proposed by Louis G. Macrory);
Alfred Edward Nicholls, Principal of King Edward VII. Nautical School, London, E. (proposed by Sir Howard Grubb); and
John Wearing, Garsdale, Sedbergh, Yorks (proposed by Thomas Weir).

Sixty-six presents were announced as having been received since the last meeting, including, amongst others:

Sir R. S. Ball, A Popular Guide to the Heavens, presented by the publishers; Royal Observatory, Greenwich, 17 charts of the Astrographic Chart of the Heavens, presented by the Observatory; B. Hasselberg, Untersuchungen über die Spectra der Metalle, No. VII. Spectrum des Wolframs, presented by the author; Count de Miremont, Popular star maps; and Practical methods in modern navigation, presented by the author; Paris, Conférence Astrophotographique International, circular, No. 11, presented by the Paris Observatory; Science Year-book, 1905, presented by Major Baden-Powell; Yerkes Observatory Publications, vol. ii., presented by the Observatory.

Sun-spots and Magnetic Storms. By Arthur Schuster, F.R.S.

At a recent meeting of the Royal Astronomical Society Mr. W. Maunder discussed the connexion between sun-spots and magnetic storms. The main portion of his results are embodied in a diagram which at once strikes the eye as supporting his views in a remarkable fashion. Having had, however, some experience of the manner in which the eye is frequently deceived by picking out striking features and adjusting itself so as to find what it is looking for, I approached the study of Mr. Maunder's paper in a somewhat doubting spirit, and took the trouble to form similar diagrams, using different arrangements of periods. The result has convinced me that, subject to certain qualifications, Mr. Maunder has made good his contention that magnetic storms are apt to recur in periods not differing much from that of the mean rotation of the sun-spot zones. This is a very important result, but in trying to fit a theory to suit new

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facts we must not forget that older and at least equally well established ones cannot be ignored, and these do not support the theoretical views which are brought forward by Mr. Maunder.

W. G. Adams and Ellis have shown that the first shock of a magnetic storm is felt simultaneously at widely separated stations of the Earth's surface, but the more detailed examination of Adolph Schmidt* has proved that the disturbing vectors in different localities are by no means parallel to each other. Nor do they at all agree with that distribution of magnetic force which would result from the motion of electric particles projected from the Sun across the Earth's path. The disturbance in reality suggests that its cause is to be found in closed ring systems of electric currents lying parallel to, and not far above, the Earth's surface, systems which are very similar to those producing the diurnal variation of the magnetic forces. There is also other evidence tending to show that the seat of the disturbance is in our atmosphere, such as the fact, well established by Ellis, that magnetic storms occur more frequently near the equinox. In fact the whole behaviour of magnetic storms, as well as the suddenness of their first impulse, is quite inconsistent with the view that they are due to the electromagnetic effects of projected particles. We may, I think, accept it as proved that their primary cause is mainly of terrestrial origin. This view is in accord with the results of Lord Kelvin's calculation on the energy which would have to be supplied by the Sun if magnetic storms were due to electromagnetic waves emanating from that body. Lord Kelvin has never published the details of the calculation, but these are easily supplied. The outer magnetic field due to a uniformly magnetised sphere of radius a has an energy equal to $M^2/3a^3$, where M is the magnetic moment of the sphere. Such a sphere exerts its greatest force at points in the magnetic axis. Let us then take the most favourable position for the direction of magnetisation, and imagine the Sun to become a magnet with one of its poles pointing straight towards the Earth. The magnetic force H on the Earth's surface would be $2M/r^3$, if r is the distance between the centres of the two bodies. Expressing M in the terms of H, we find for the energy of the magnetic field outside the Sun's body $H^2r^6/12a^3$. Substituting numerical values ($r = 214R$; $R = \cdot 7 \times 10^{11}$; $H = \cdot 0005$) we find $\cdot 69 \times 10^{39}$ ergs for the amount of energy. In the particular storm discussed by Lord Kelvin the change of ·0005 in the magnetic force took place in the course of twenty-five minutes; the average work done per second is found by dividing the total energy by 1500, thus giving $\cdot 46 \times 10^{36}$ ergs per second. This is about one-third of the value given by Lord Kelvin, but the discrepancy may easily be due to a difference in one of the suppositions made. If we had, *e.g.*, imagined the axis of solar magnetisation to stand at

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* *Meteorologische Zeitschrift*, vol. xvi. p. 385 (1899).

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right angles to the ecliptic the work to be done would be four times as great, and a further increase would result from taking the magnetic field within the solar surface into account.

Mr. Maunder endeavours to get over the very formidable objection which Lord Kelvin's calculation has raised against any theory which makes the Sun responsible for the energy of magnetic storms, by supposing this energy to radiate only along lines emanating from certain restricted regions of the Sun's surface. But, apart from the fact that a radiation of electromagnetic waves in restricted directions is impossible, the supposition does not help him, because the radiating surface would be diminished in the same ratio as the total amount of energy. Lord Kelvin's *reductio ad absurdum*, following from his calculation that the active portions of the Sun's surface would, in a moderate storm, emit during eight hours as much energy as the same portion of the solar surface does during four months in its regular supply of heat and light, would still remain. It may be urged that the particular theory which is apparently favoured by Mr. Maunder contemplates quite a different propagation of energy from that which underlies Lord Kelvin's calculation. That is quite true, but it is not possible to calculate the energy supply on the theory of projected particles, because that theory leaves all energy considerations out of account. If the Sun were, as supposed, sending out a continuous stream of negatively electrified particles, a highly electrified positive Sun would be left behind, and this positive electrification would continuously increase. The projection would have to take place, therefore, against strong electric forces, and work would have to be done not only in supplying the electromagnetic field, but also in overcoming electrostatic force. The theory gives no clue as to why the continuously increasing positive charge should not ultimately counterbalance the forces which tend to drive negative electrons out of the Sun. Confining ourselves to the electromagnetic field of a straight electric current, and neglecting all return currents, it is easily seen that the energy supply would have to be infinitely great. This, of course, shows that the return current cannot be neglected, and this again shows, as already stated, that the theory is not one to which in its present form energy considerations can be applied.

I am not arguing against the view that electric discharges may take place within the region of the Sun's corona, but only against the theory that such discharges can account for the energy supply of magnetic storms. It is not necessary to pursue this part of the subject further, as apart from the arguments given the theory of projected particles does not account for the electromagnetic effect observed in a magnetic storm. We may turn, therefore, to the statistical portion of Mr. Maunder's paper.

If a large number of independent events are arranged in any period whatsoever it will frequently occur that two take place near the same phase in two successive periods. But with the number of storms treated by Mr. Maunder (and considering the

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length of the period) it could only happen in exceptional cases that one should take place within a few hours of the same phase in three or more successive periods. I have convinced myself of this by taking periods slightly differing from that of the solar rotation and examining their periodic recurrence. We may, therefore, accept it as proved that magnetic storms show some kind of periodicity, the length of the period being somewhere near 27·27 days. Looking at the matter without any preconceived opinions at all—and a preconceived opinion formed on previous knowledge is quite legitimate—Mr. Maunder's work does not necessarily compel us to admit that this period is due to solar influence. The sidereal and anomalistic months, for instance, have periods which are so nearly equal to that of the Sun's rotation that for a period of two or three rotations a lunar action could not be distinguished from one due to the Sun, and Mr. Maunder's results are quite consistent with the view that the active body is the Moon and not the Sun. The solar action may be more probable, owing to the undoubted connexions already established, but speaking purely of the conclusions which can logically be drawn from Mr. Maunder's statistics independently of other arguments the possibility of lunar action is equally indicated.

In order to clear up my own ideas on the point I have applied a method which I have already advocated and used in several publications. If a number of events like earthquakes or magnetic storms are arranged in any period whatsoever, we may calculate the coefficients of the periodic series which, according to Fourier, completely represents the succession of events. If the events are quite unconnected we may calculate independently the expectancy of the Fourier coefficients and the probability that any particular coefficient should exceed a given amount. If there are m events, and the value $1/m$ is given to each, so that their total sum is numerically expressed by unity, and if, further, a and b represent the two coefficients belonging respectively to the cosine and sine of any arbitrarily assumed period, the expectancy of a^2+b^2 is $4/m$, and the probability that a^2+b^2 should be greater than $4k/m$ is $e^{-\kappa}$. The quantity a^2+b^2 I call, for shortness, the intensity of the particular period. These results hold only on the supposition that all events are quite independent. If there is a real period which affects them, then for this particular period we shall, if m is sufficiently large, obtain a coefficient substantially larger than the expectancy, and the method supplies, therefore, a criterion for such a real periodicity. But in the case contemplated by Mr. Maunder no real periodicity is suggested by him, but only the probability of the recurrence of the event after a certain length of time. I foresaw this case in my first publication on the subject,* and showed that here also the squares of the

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* *Terrestrial Magnetism*, vol. iii. p. 13 (1898).

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Fourier coefficients would be increased by the recurrence. If magnetic storms were to occur always in groups of two, separated by a definite interval, the expectancy of the intensity would be doubled for all periods which are multiples of the interval.

In Table I. I have collected the results obtained by using Mr. Maunder's list of magnetic storms and taking the times given by him for the commencement of the storms. Arranging these times in periods, there is no difficulty in obtaining the Fourier coefficients by well known processes. The first column gives the period chosen, while the second column contains the values of the intensity belonging to this period. If we take a period equal to one-half that given in the first column we obtain the corresponding squares of amplitude as given in the third column; similarly the next three columns give the values of a^2+b^2, where the period is the nth part of that given in the first column, the number being placed at the head of each column. These mean values of the different columns and rows are also given, and finally the expectancy for each period. The total number taken account of was 270, and hence the expectancy is $\frac{4}{270}$.

Table II. gives similarly the results when the period is that of the synodic revolution of the Moon. The number of storms taken into account was 278 in this case, and the corresponding expectancy is ·0144. The numbers were arranged so that the whole period of the lunar month was subdivided into thirty parts. This made it easy to calculate the Fourier coefficients for seven different subdivisions of the period. The mean value of the squares of the amplitudes coincides, to the number of decimal places given, with the expectancy, thus giving a satisfactory confirmation to the treatment of the problems by the theory of probability.

Table I.

Period in Days.	1.	2.	3.	4.	9.	Mean.	Expectancy.
27·250	·0365	·0121	·0053	·0059	·0021	·0143	·0148
27·278	·0073	·0878	·0165	·0457	·0258	·0366	·0148
27·333	·0081	·0088	·0187	·0100	·0258	·0123	·0148
27·542	·0560	·0046	·0061	·0124	·0021	·0162	·0148
Mean	·0290	·0283	·0116	·0162	·0140	·0199	...

Table II.

n	$a_n^2+b_n^2$	n	$a_n^2+b_n^2$
1	·0177	6	·0011
2	·0231	10	·0407
3	·0053	15	·0031
5	·0098	Mean	·0144
		Expectancy	·0144

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There is, then, no evidence of a period depending on the lunation, but the interpretation of Table I. is somewhat perplexing. Leaving for a moment the period of 27·278 days out of consideration, the average square of the amplitude is ·0143, which agrees closely with the expectancy calculated on the supposition that magnetic storms are distributed quite at random without any relation to solar rotation. But the period temporarily omitted alters the aspect of the question. Were we to look at this table from the purely statistical point of view we should be justified in concluding, with some degree of probability, that there is a definite period of $\frac{1}{2} \times 27{\cdot}278 = 13{\cdot}64$ days in the breaking out of magnetic storms; for the ratio of the actual to the expected intensity is 5·9, and the probability of the accidental occurrence of this ratio is three in a thousand. This, of course, is not sufficient for anything amounting to a proof, but it gives at any rate a certain presumption in favour of a real connexion. It is certainly remarkable that for four out of five of the coefficients calculated the amplitude is greater than what is to be expected on the supposition of a random distribution. A closer examination of the numbers from which the Fourier coefficients have been derived shows that the period of 13·64 days is due to the fact that during certain parts of the twenty years examined storms were apt to occur in greater quantity when the longitude of the Sun's centre was somewhere between 55° and 90°, and that at other times the occurrence predominated when the longitude of the Sun's centre differed from the above by about 180°.

According to Mr. Maunder's view that a magnetic storm, whenever it occurs, is apt to be followed by another storm at intervals of time which vary according to the particular solar latitude which determines the storm, the expectancy for the intensity of all the periods in Table I. should be raised.

The table, as far as it goes, does not support this view. Nevertheless it cannot be said that there is a definite contradiction to it. We have, in fact, the choice between two interpretations.

1. Magnetic storms are apt to occur at times which, starting from a certain point, are multiples of 13·64 days. During some years the odd multiples, and during other years the even multiples, are principally concerned.

2. Magnetic storms often recur after several successive intervals which are equal to some lapse of time sufficiently near 27·28 days to fall within the limits of rotation of the sun-spot zones.

The first alternative is that more directly indicated by the above reduction of observations. It would explain all results obtained by Mr. Maunder, but its acceptance would involve the necessity of believing in the existence of some definite period equal to 27·28 days. As different sun-spot zones rotate with different velocities this would mean either that sun-spots have nothing to do with the phenomenon or that only the sun-spot

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zones having that particular time of revolution are concerned. It would also mean that the activity is to some extent concentrated on definite meridians. There are great difficulties in the way of accepting this conclusion. On the other hand the second alternative, though it presents fewer theoretical difficulties, would compel us to assume that the exceptional values of the coefficients in the period of 27·278 days is accidental. If we accept the second alternative, and take the mean of all intensities collected in Table II. as the expectancy which corresponds to periods equal approximately to the solar rotation, I calculate that the probability of an accidental occurrence of an intensity of ·0878 is ·009, or nearly one in a hundred. In twenty trials we should have, therefore, obtained a number which on the average should only occur once in a hundred trials. The probability that the average of five observations should be ·0366 is about one in twenty-one, *i.e.* in the natural course of calculation we should find that, by taking the average of five intensities, we should get one case in twenty-one where its value is equal to or greater than the number found. In our trials we have actually found one case out of four. The possibility of accident is, therefore, considerable, yet the curious fact that it is just that one period which corresponds to Carrington's adopted value for the mean solar rotation is remarkable, and invites further investigation.

It would be important to discuss in this respect the Greenwich photographs of magnetic disturbances prior to 1882. This would in all probability allow us to decide which of the two above alternative interpretations is the correct one.

The first part of our discussion has shown us that the energy of magnetic storms is of terrestrial origin; in the second we have come to the conclusion that, in some form or other, storms recur at intervals apparently identical with that of the revolution of the sun-spot zones. We must now try to reconcile the two results. It will be useful to calculate, in the first instance, the energy involved in these storms, assuming them to be due to electric currents circulating in our atmosphere. It will be allowable to consider these currents to be confined to a spherical shell having a radius equal to the Earth's radius.

For the energy of the magnetic field we have, if Ω is the magnetic potential,

$$E = \frac{1}{8\pi}\int \frac{d\Omega}{dn} dS,$$

where the integration is to be extended over the surface, n being taken in the direction of the normal drawn inwards for the outer field, and outwards for the field which lies inside the shell. The magnetic field of the disturbing currents overlaps that of the Earth, and there may occasionally be a diminution instead of an increase of energy; but, on the supposition that the two are independent, we may say that on the average there is an increase in energy equal to that required for the establishment of the dis-

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turbing field taken by itself alone. We express that field in terms of its spherical harmonic components, and may therefore write outside the shell

$$=\frac{A_n a^n S_n}{r^{n+1}},$$

inside the shell

$$=\frac{A_n r^n S_n}{a^{n+1}}.$$

In these expressions a is the radius of the Earth, r the distance from the centre of the Earth, A_n a constant, and S_n a surface harmonic of degrees n, being of the form

$$\cos \sigma\phi \frac{d^\sigma P_n}{d\mu^\sigma},$$

where P_n is the zonal harmonic of degree n and μ the cosine of the colatitude.

Substituting in the integral we easily find for the energy of the whole field

$$E=\frac{2n+1}{8\pi a^3} A_n^2 \int S_n^2 ds,$$

and finally making use of well known properties of spherical harmonics

$$E=\frac{(n+\sigma)\,!}{(n-\sigma)\,!} \frac{A_n^2}{4a}.$$

If $\sigma = 0$ the expression is to be doubled.

For the sake of simplicity consider the horizontal magnetic force at a point of the equator (referred to the axis of reference). Its maximum value lies north and south when $n-\sigma$ is odd, and east or west when $n-\sigma$ is even. Its intensity H may be expressed in the form

$$Ha^2 = kA_n,$$

where k is a numerical factor.

The energy of the field in terms of H is

$$E=\frac{(n+\sigma)\,!}{k^2(n-\sigma)\,!} \frac{a^3H^2}{4}.$$

Table III. gives the values of $(n+\sigma)\,!/k^2(n-\sigma)\,!$ when n is three or less.

TABLE III.

n	1	2	3
1	2	...	...
2	$\frac{2}{3}$	$\frac{2}{3}$	...
3	$\frac{16}{3}$	$\frac{30}{225}$	$\frac{16}{45}$

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To get an idea of the order of magnitude we may take the case $n = 1$, $\sigma = 1$, so that the energy is equal to $\frac{1}{2}a^3H^2$. Applying this to the case of the Earth, and to the same magnetic storm discussed above, in which H increased by ·0005 in twenty-five minutes, we find

$$E = 3{\cdot}22 \times 10^{19},$$

and for the rate of doing work $2{\cdot}15 \times 10^{16}$ ergs per second, or 2·82 million horse power. The power is equal to that required to heat 7700 metric tons of water in twenty-five minutes from the freezing to the boiling point of water. It is thus seen that, though the actual force measured by our magnetographs may only be equal to the weight of one-hundreth part of a milligram, the total work done in a general storm affecting the whole Earth simultaneously is very large indeed. The large numerical value obtained limits us, as far as I can judge, to three alternative explanations of the origin of magnetic storms.

1. Our calculation of the energy required is based on the supposition that the magnetic field is independent of others on which it is superposed. But there may not be such an independent addition to the existing magnetic forces, but only a change in direction. Thus when we produce an artificial magnetic storm by moving magnetic masses in the neighbourhood of our instruments no energy is required, because the magnetic field remains the same relative to the magnet, though it is shifted in space. Similarly, in the diurnal variation of terrestrial magnetism no energy has to be supplied except that required to overcome the ohmic resistance of the conductors through which the currents are passing, because the magnetic changes are here produced by a rotation of a magnetic system which does not change relatively of itself. We might, therefore, suppose that a portion of the magnetic forces which are observed on the surface of the Earth are due to some external electric currents. As long as these rotate with the Earth there is no disturbance, but if for some reason the position of these currents relatively to the Earth were disturbed strong magnetic forces might come into play. In such a case our calculation would not apply. It is quite likely that a small portion of the normal magnetic field of the Earth is due to outside currents, but I do not consider that this portion can be sufficiently large to cause by means of its sudden variations the forces observed in magnetic storms.

2. We might imagine that the heat energy contained in our atmosphere is sufficient to supply the work done in magnetic storms. We find, indeed, that a lowering of temperature of the thousandth part of one degree throughout the mass of the atmosphere would be sufficient to supply the required work. But we must reject this theory, because only a small part of the atmosphere can be concerned in a magnetic storm, and because we do not know of any manner in which the heat of a gas can be converted into electromagnetic energy.

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3. We are now left with the one remaining source of energy, which is sufficient for our purpose. That is the *vis viva* of the Earth's diurnal rotation. In C.G.S. units that energy is expressed by 26×10^{35}. That this energy, if we can find means of applying it, is capable of maintaining magnetic storms may be shown by a simple calculation. Suppose that a storm, on the average, lasts in full force forty times the twenty-five minutes we have considered in the typical case, and that we have 100 such storms in one year. The energy drawn away from the Earth would gradually diminish its rotational velocity, but so slowly that after provision has been made for the supplying of magnetic storms during a million years the Earth, as a time-keeper, would then be losing at the rate of only one second per year. Even a layer of air, at atmospheric pressure of the tenth part of a millimetre thick, has an energy of rotation more than two thousand times greater than that required for the production of a magnetic storm lasting twenty-five minutes.

Having been led to what seems to be the only available source of energy we must try to form some idea as to the manner in which the frequency of the magnetic storms may be influenced from outside, while their primary cause lies within the terrestrial atmosphere. It is important for this purpose to keep in mind that the intensity of an electric current always depends on two things—electromotive force and resistance. The electromotive force must supply the energy, but the resistance of air is affected by outside agencies, such as corpuscular emissions or ultraviolet radiation. When I discovered, in 1887, that a gas may artificially be brought into such a state that it ceases to behave as an insulator even to the smallest electromotive force, I at once pointed out the bearing of this on some phenomena of terrestrial magnetism, and suggested, in my first publication on the subject, that the greater amplitude of the diurnal variation may be accounted for by the greater conductivity of the outer regions of the Earth's atmosphere when the number of sun-spots is great.* Returning to the same subject in the concluding portion of my Presidential Address to Section A of the British Association at Edinburgh, I further suggested that both the periodicity of sun-spots and the connexion between these spots and magnetic disturbances on the Earth may be due to a periodically recurring increase in the electric conductivity of the parts of space surrounding the Sun. Since then the possibility of corpuscular projections has been discovered. Such corpuscular projections do, in passing through gases, invariably increase the electric conductivities. Ultraviolet light acts in the same way, provided it falls on sufficiently large conglomerations of matter. Without forming, therefore, any very definite theory we may accept the view that there is some solar effect propagated in straight lines which may increase the electric conductivity of the atmosphere,

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* *Proc. Roy. Soc.* vol. xlii. p. 371 (1887).

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and therefore set a magnetic storm going without supplying its energy.

The effects we must assume to be propagated in straight lines, because curved rays are impossible to explain unless we assume sufficient matter in interplanetary space to give it permanent conductivity. The curvature might result from an irregular distribution of such matter, and would not, in that case, revolve with the Sun, but curved rays are only required if we wish to connect directly the solar influence with sun-spots. For this supposition I can see no necessity at present.

The sudden breaking out of a magnetic storm suggests the analogy of the passage of an ordinary electric spark, which is set going by ultraviolet radiation or radioactivity. The electromotive force being supplied, no passage of electricity takes place as long as there is insufficient conductivity. A small quantity of radium brought into the neighbourhood of the electrodes may impart the necessary conducting power, and the spark then will break through the air gap.

It has been shown that the Earth's rotation must supply the energy, and this it can only do if the electric currents are induced by motion across the Earth's lines of force.

All relative motion between any extensive portion of the Earth's atmosphere and the Earth itself sets up an electromotive force which may produce currents of sufficient intensity to affect our magnetometers. The diurnal variation agrees with the effects which we should expect from the horizontal flow which must accompany the atmospheric waves which we observe directly in the diurnal variation of the barometer. Similarly the general effect of convection currents being in the direction of equalising angular momentum in different parts of the atmosphere, there must be a general drift from east to west in the equatorial, and from west to east in the polar regions. This sets up an electromotive force towards the equator in the polar regions, and downwards in the equatorial regions. Again, near the limits of our atmosphere, if there is any conducting matter not rotating with the same angular velocity as the Earth, currents will be produced, and in each of these cases a sudden variation of conducting power might set a magnetic storm going. If the resistance be diminished in any region—as, *e.g.*, along a short stretch of a meridian circle at a place where the electromotive force runs north and south—the resulting effects would be very similar to those sketched out by Dr. A. Schmidt as actually occurring in magnetic storms.

This attempt at an explanation is only brought forward in order to show that there is no impossibility of accounting for the observed disturbances in a perfectly rational manner. The theory requires, however, to be worked out quantitatively before its value can be finally tested. The difficulty begins when we wish to explain the manner in which solar phenomena affect the sequence of events. At present we are only able to form more

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or less plausible guesses as regards the necessary mechanism, but the particular guess ventured upon by Mr. Maunder is not, I think, consistent with well established facts. I cannot, therefore, agree with his somewhat boastful claim that he has rendered clear what Lord Kelvin has called a "fifty years' outstanding difficulty." He has, no doubt, added a new fact and made an important contribution to the subject. He has given renewed interest to it and brought out the urgent importance of further investigation, but the mystery is left more mysterious than ever; the facts have become harder to understand and more difficult to explain.

Magnetic Storms and associated Sun-spots. By the Rev. A. L. Cortie, S.J.

The first and most important conclusion of Mr. Maunder's paper on "Magnetic Disturbances, 1882 to 1903, as recorded at the Royal Observatory, Greenwich, and their Association with Sun-spots" (*Monthly Notices, R.A.S.* vol. lxv. No. 1, 1904 November) is, that the origin of magnetic disturbances on Earth lies in the Sun, and not in any body or bodies affecting both. That is, that the Sun is the seat of the efficient cause of our magnetic storms, for evidently Mr. Maunder is not speaking of a mere condition. And the premisses for this conclusion are: first, that the magnetic storms mark out the synodical rotation-period of the Sun; and secondly, that what marks out the synodical rotation of the Sun must be caused by something in the Sun—this second premiss is implied, but not expressed, and is not necessarily true—therefore the cause of magnetic storms lies in the Sun. But the argument of Mr. Maunder is faulty, in that it omits at least one other alternative: namely, that both the magnetic storms on Earth, and the magnetic centres on the Sun associated with sunspots, which are presented to the Earth at successive synodical rotations, may have a common cause which is neither on the Sun nor on the Earth. This latter alternative is consonant with the theory proposed by Father Sidgreaves in his memoir "On the Connexion between Solar Spots and Earth Magnetic Storms" (*Memoirs, R.A.S.* vol. liv. p. 91). For when two sets of connected phenomena are found regularly to concur, the logical conclusion is not necessarily that one is the cause of the other, but that either one is the cause of the other, or they have a common cause. It is this latter alternative of which Mr. Maunder has omitted to take account, and which renders his syllogism out of form. Therefore, even were he to prove his first premiss—namely, that magnetic storms mark out the synodic rotation-period of the Sun—up to the hilt, it would still not